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(54) Vehicle front-view monitoring system

(57) A vehicle front-view monitoring system determines whether there is a fail occurring on the monitoring system based on luminance data on an image of a front view taken by camera (1, 2) and takes fail-safe measures if the fail is occurring. The luminance data indicates luminance-distribution characteristic values (VAR) indicating horizontal luminance-distribution on the image. A fail can be determined based on a parameter obtained by normalizing the luminance-distribution characteristic values (VAR') by a shutter speed (a) for the camera equipment.

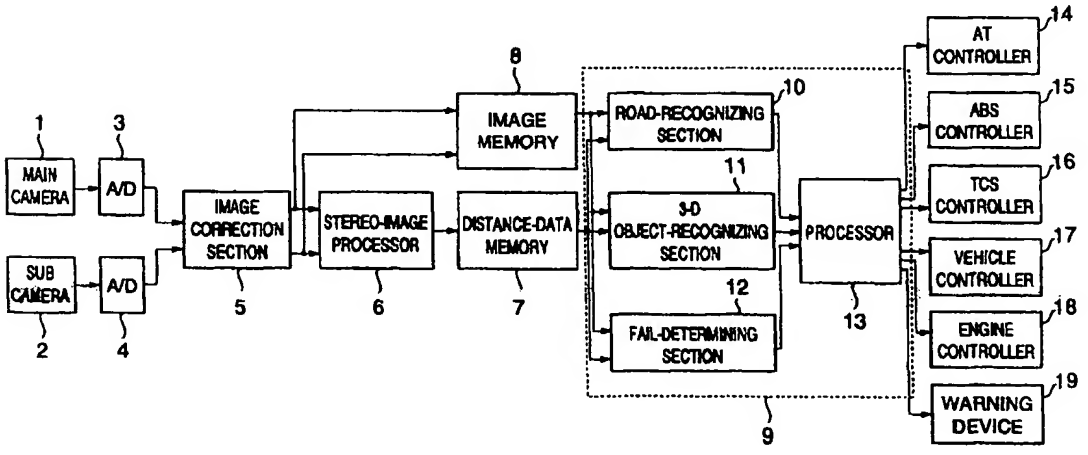

FIG.4

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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a vehicle front-view monitoring system having a function of taking fail-safe measures against images irregularly monitored due to sunlight interference.

[0002] The vehicle front-view monitoring system having CCD cameras has recently attracted much attention. The system recognizes driving conditions such as a distance to a vehicle travelling ahead based on images taken by the cameras and warns a driver of danger or controls the vehicle such as by shiftdowns.

[0003] Recognition of the driving conditions using a stereo-distance measuring technique obtains a positional difference (parallax) on an object in a pair of the images and calculates the distance to the vehicle travelling ahead by trigonometrical survey.

[0004] Such a vehicle front-view monitoring system requires fail-safe measures for securing safe driving. A failure to be detected is a fault monitoring condition such that the vehicle in front is beyond recognition while monitoring cameras are facing weak sunlight.

[0005] Image monitoring failures are discussed with reference to FIGS. 1 to 3.

[0006] When monitoring vehicles traveling ahead (FIG. 1) while facing weak sunlight, disc-like diffusion could appear on the monitored image, as illustrated on the left-upper side in FIG. 2, due to saturation of luminance. Such a disc-like diffusion appearing on the monitored image while the vehicle is facing the sunlight is called a sunlight-diffusion disc hereinafter. These sunlight-diffusion discs cause the saturation of pixel luminance on the disc areas and the surrounding areas. A correct image data therefore can not be obtained, or vehicles in front are masked by the sunlight-diffusion discs, which results in monitoring failures. Moreover, the disc edges have a big luminance change between adjacent pixels in the horizontal direction and hence incorrect distance data could be calculated on the edges.

[0007] FIG. 3 illustrates distance-data calculation based on stereo images (a reference image and an image to be compared such as shown in FIG. 1).

[0008] In FIG. 3, black sections have a big luminance change between the adjacent pixels in the horizontal direction. These sections carry distance data (depth). The intensities of most pixels in the sunlight-diffusion disc area have been saturated, so that no distance data is calculated in this area (a lost state). Moreover, the disc edges have a big luminance change in the horizontal direction, so that the incorrect distance data could be calculated.

[0009] Ensuring safe driving in such a fault condition due to a generation of the sunlight-diffusion discs discussed above requires the fail-safe measures to temporarily halt the monitoring function.

SUMMARY OF THE INVENTION

[0010] A purpose of the present invention is to provide a vehicle front-view monitoring system for monitoring optical irregularities occurring on monitored images and swiftly taking fail-safe measures.

[0011] The present invention provides the vehicle front-view monitoring system for taking the fail-safe measures comprising: a camera device for taking an image of a view in front; a calculator for calculating luminance data on the image; and a determination section for determining whether there is a fail occurring on the monitoring system based on the luminance data, the fail-safe measures being taken if the fail is occurring.

[0012] By way of example only, a specific embodiment of the present invention will now be described with reference to the accompanying drawings, in which:-

FIG. 1 illustrates a normal image monitored on a monitor screen;
FIG. 2 illustrates an irregular image monitored on the monitor screen on which sunlight-diffusion discs are generated;
FIG. 3 illustrates the irregular image monitored on the monitor screen, including inaccurate distance data due to generation of sunlight-diffusion discs;
FIG. 4 is a block diagram of a preferred embodiment of the vehicle front-view monitoring system according to the present invention;
FIG. 5 shows a flow chart of a weak-sunlight-facing driving determination routine;
FIG. 6 shows a flow chart of a weak-sunlight-facing driving determination routine;
FIG. 7 illustrates the upper and lower areas set on the monitor screen;
FIG. 8 illustrates an area on which a vehicle travelling ahead is monitored;
FIG. 9 illustrates a monitoring area;
FIG. 10 illustrates measured luminance-distribution characteristic parameters;
FIG. 11 illustrates normalized luminance-distribution characteristic parameters;
FIGS. 12A and 12B illustrate luminance addition characteristics in normal driving,

FIGS. 13A and 13B illustrate luminance addition characteristics in weak-sunlight-facing driving;
FIGS. 14A to 14C illustrate luminance center;
FIG. 15 shows a flow chart of a fail determination routine;
FIG. 16 shows a flow chart of a count-up amount setting routine;

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0013] Preferred embodiments according to the present invention will be disclosed with reference to the attached drawings.

[0014] Fig. 4 shows a block diagram of a preferred embodiment of a vehicle front-view monitoring system according to the present invention.

[0015] A pair of cameras 1 and 2 having image sensors such as CCDS are attached to a vehicle such as an automobile in the vicinity of tyres with a predetermined distance (corresponding to camera-baseline length) in the direction of vehicle width, for taking images ahead.

[0016] The main camera 1 (right camera) takes a reference image required for stereo processing whereas the sub-camera 2 (left camera) takes an image to be compared.

[0017] Analog images taken by the cameras 1 and 2 while the main camera 1 and sub-camera 2 are synchronized with each other are converted into a specific luminance gradation (for example, gray scale at 256 gradations).

[0018] The digitized images are processed by an image correcting section 5 for correction of luminance, image geometrical conversion, etc. An inevitable misalignment on the cameras 1 and 2 will affect left and right images. Such effect can be cancelled by geometrical conversion such as an image rotation and a parallel shift with Affine conversion, etc. Luminance data on the stereo images (a reference image and an image to be compared) for one frame corrected by the image correcting section 5 are stored in an image memory 8.

[0019] The luminance data are further supplied to a stereo-image processor 6 for calculating distance data (parallax for each object). Each distance data corresponds to a positional deviation on the same object in the stereo images. An actual distance to the object is defined on the basis of parallax by a trigonometrical survey. The distance data for one frame thus obtained are stored in a distance-data memory 7.

[0020] The luminance data and the distance data are supplied to a microcomputer 9.

[0021] The microcomputer 9 includes a road-recognizing section 10, a three-dimensional (3-D) object-recognizing section 11, a fail-determining section 12 and a processor 13.

[0022] In response to the luminance and distance data, the road-recognizing section 10 recognizes the condition of a road ahead, and the 3-D object-recognizing section 11 recognizes three-dimensional objects (vehicles travelling ahead).

[0023] Based on the data from the sections 10 and 11, the processor 13 warns the driver of a danger via a warning device 19 such as a display or a speaker when it determines that the warning is necessary.

[0024] Moreover, the processor 13 controls several controllers 14 to 18 if necessary. For instance, it sends a command signal to an automatic transmission (AT) controller 14 for downshifts or to an engine controller 18 for an engine power-down. The processor 13 may further send the command signals to an antilock-braking system (ABS) controller 15, a traction control system (TCS) controller 16 and a vehicle controller 17 for controlling an engine speed and a torque distribution to tyres, etc.

[0025] The fail-determining section 12 determines whether the cameras 1 and 2 are taking the images into the sun and a fail is occurring, based on the luminance and the distance data stored in the image memory 8. The vehicle and the warning controls are interrupted by the fail-safe measures for prevention of malfunction which could otherwise occur due to lowering in monitoring accuracy during a period of determination in that a fail is occurring, or of "1" set for a fail flag NG which will be described later.

[0026] FIGS. 5 and 6 show flowcharts for indicating a routine of determining whether the cameras 1 and 2 are taking images into the sun while the vehicle is facing the sunlight, which is called a sunlight-facing driving hereinafter. The routine is repeated by the fail-determining section 12 by a predetermined interval (a cycle of 100 ms for example).

[0027] The requirements for taking the fail-safe measures (called fail-safe measure-interruption requirements hereinafter) are discussed before explaining the routine in detail.

[0028] Requirements for steps S1 to S6 are necessary for taking the fail-safe measures in the present invention. It is determined that the cameras 1 and 2 are taking the images into the sun only when all the fail-safe measure-interruption requirements are met in steps S1 to S6 and the routine proceeds to step S12 whereas to step S7 if not met in any one of steps S1 to S6.

[0029] As disclosed later, the fail determining section 12 determines whether the fail-safe measure-interruption requirement or a fail-safe measure-release requirement is met and performs counter increment or decrement in accordance with a result of determination. The fail-safe measure-release requirements are the requirements for resuming functions that have been interrupted by taking the fail-safe measures.

[0030] The interruption requirements are required for determining whether the cameras 1 and 2 are taking images into the sun, so that the fail-safe measures should be taken. A counter increment is performed when an interruption requirement is met. The fail-safe measures will never be taken before the counter reaches a predetermined value, even if the interruption requirements are met.

[0031] The release requirements are required for determining whether to halt the counter increment. In the present invention, the counter starts a count-up when an interruption requirement is met and continues until a release requirement is met even though monitoring situation is changing and no interruption requirement is met anymore.

[0032] The present invention deploys the following six interruption requirements for taking fail-safe measures, however, any combination of at least two of the requirements or addition of other requirements are available.

[0033] First Requirement: No vehicle is recognized ahead, or no distance to a vehicle in front is calculated (step S1).

[0034] The fail-safe measures will be taken in the present invention when the cameras 1 and 2 are taking the images into the sun (sunlight-facing driving condition) so that the vehicle that actually traveling ahead is lost on a monitor screen of the monitoring system. In other words, the fail-safe measures will not be taken even though the sunlight-diffusion discs shown in FIG. 2 are appearing while the vehicle traveling ahead is recognized.

[0035] The present invention therefore deploys a decision in that no vehicles are recognized ahead as a fail-safe measure-interruption requirement. This decision step is executed even though no vehicles actually exist ahead.

[0036] When the requirement in step S1 (FIG. 5) is met, the routine proceeds to step S2 to determine whether the cameras 1 and 2 are taking the images into the sun (sunlight-facing driving condition).

[0037] Calculation of the distance to the vehicle in front in step S1 is explained before disclosing the step S2.

[0038] The distance to the vehicle in front is calculated in combination of a stereo-distance measuring technique and an image-recognition technique.

[0039] Calculated first is a lane model that indicates a three-dimensional shape of a road ahead. Lane markings painted on the left and right sides of a lane and displayed on the monitor screen have the luminance higher than that of the road surface. The markings are extracted as areas having luminance edges on the borders between that and the road surface.

[0040] The parallax on the lane thus extracted is calculated for each (4 x 4)-pixel block, for example. A two-dimensional position and the parallax in the monitored image for one pixel block in which the lane is displayed provide a three-dimensional position and a distance of the lane portion by using a known coordinate conversion formulas.

[0041] The calculated three-dimensional lane distribution is approximated into a straight line for a predetermined segment. The straight lines are connected into a polygonal line for calculating the lane model.

[0042] The vehicle travelling ahead is recognized as a three-dimensional object existing on the area (road surface) surrounded by left and right lane models. The distance to the vehicle in front is calculated based on the parallax of the object.

[0043] These techniques are disclosed in detail in Japanese Patent Application No. 11-269578 (road recognition) and Japanese Unexamined Patent Publication No. 5-265547 (recognition of vehicle traveling ahead).

[0044] Second Requirement: A shutter speed "a" is equal to or lower than a predetermined reference speed (step S2).

[0045] The shutter speed tends to be higher in a sunlight-facing driving condition in which the vehicle in front is missing on the monitor screen than that in a usual driving condition. In view of this tendency, an appropriate reference shutter speed such as 2000 μsec is set.

[0046] The present invention deploys a decision in that the shutter speed "a" is lower than this reference shutter speed as a fail-safe measure-interruption requirement.

[0047] The shutter speed, however, tends to be extremely higher against a strong sunlight in mid-summer, for example 200 μsec. or lower. In view of this tendency, the routine proceeds to step S3 (FIG. 5) when the requirements in steps S1 and S2 are both met.

[0048] Third Requirement: The upper luminance saturation factor LR1 is larger than the lower luminance saturation factor LR2 (step S3).

[0049] Sunlight-diffusion discs images shown in FIG. 2 will be generated on the upper side of the monitor screen when a vehicle in front is missing during sunlight-facing driving. This phenomenon has a tendency in that the luminance saturates on the upper side.

[0050] In view of this tendency, as illustrated in FIG. 7, the upper and the lower areas are provided in a reference image.

[0051] The present invention deploys the decision in that the upper luminance saturation factor LR1 in the upper area is larger than that of the lower luminance saturation factor LR2 in the lower area as a fail-safe measure-interruption requirement.

[0052] The luminance saturation factors LR1 and LR2 correspond to a ratio of the number of pixels for which luminance has saturated (for example, the luminance 240 or more) to the total number of pixels in the upper and the lower areas, respectively.

[0053] The requirement in step S3 could be met even though no sunlight-diffusion discs (FIG. 2) are generated, e.

g. when there is no shielding in a fair day or while travelling on a bridge. In view of this, the routine proceeds to step S4 (FIG. 5) when the requirements in steps S1, S2 and S3 are all met.

[0054] No reference values are sec for the upper and lower luminance saturation factors LR1 and LR2 in this embodiment. This is because factors tend to vary very largely according to the driving conditions. Particularly, the lower factor LR2 often becomes zero in a normal driving condition.

[0055] Fourth Requirement: The number of luminance edges EN for an area of the vehicle in front is smaller than a predetermined reference number (step S4).

[0056] While the vehicle travelling ahead is missing on the monitor screen during the sunlight-facing driving, the number of the luminance edges EN on the sunlight-diffusion disc area (FIG. 2) tends to become extremely small.

[0057] The number of the luminance edges EN indicates the number of a pair of adjacent pixels in the horizontal direction on the monitor screen for which variation in luminance is more than a predetermined reference value.

[0058] As illustrated in FIG. 8, a vehicle in front area is set in the upper-mid section of the monitor screen, in which the vehicle travelling ahead would be displayed.

[0059] The present invention deploys the decision in that the number of the luminance edges EN in the vehicle in front area (FIG. 5) is smaller than an appropriate reference number as a fail-safe measure-interruption requirement.

[0060] This requirement could, however, be met in driving at night, in tunnel, mist, smoke or on a snowy road. In view of this, the routine proceeds to step S5 (FIG. 5) when the requirements in steps S1, S2, S3 and S4 are all met.

[0061] The number of the calculation of the distance data in the vehicle in front area can be used instead of the number of the luminance edges EN. This is because the number of the luminance edges EN and the number of the calculation of the distance data have a strong correlation in a stereo-matching, or the lager the number of the luminance edges EN, the larger the number of the calculation of the distance data.

[0062] Fifth Requirement: The luminance-distribution-characteristics parameter normalized by using a shutter speed "a" meets a requirement.

[0063] As shown in FIG. 9, several slit-like monitoring areas Ni are arranged on the upper side of the monitor screen in the horizontal direction. The reason for the arrangement of monitoring areas Ni on the upper side is that the luminance mostly varies on the upper side when the vehicle is facing a weak sunlight.

[0064] The monitoring areas Ni are provided for evaluating the luminance-distribution characteristics for a monitored image in the horizontal direction.

[0065] For example, a reference image is divided into blocks of 16 pixels each in the horizontal direction when the reference image is composed of 200 and 512 pixels in the vertical and horizontal directions, respectively. Therefore, 32 monitoring areas Ni of (200 x 16) pixels are set.

[0066] Calculated next is addition of luminance Ai for each monitoring area Ni. The addition of luminance Ai for a monitoring area Ni can be calculated by adding the luminance of sample pixels that are uniformly distributed over the monitoring area Ni The added luminance of the sample pixels may further be averaged.

[0067] The addition of luminance Ai is the value, for example, obtained by adding the luminance of 4 pixels sampled in the horizontal and vertical direcrtions each. Pixels uniformly distributed over the monitoring area Ni can be used for calculating the luminance over the area Ni with less amount of calculation. The addition of luminance Ai can be calculated for all pixels involved in the area Ni if the amount of calculation is out of the question.

[0068] The Ai-distribution characteristics for the 32 monitoring areas corresponds to the image distribution characteristics in the horizontal (lateral) direction

[0069] The parameter (luminance-distribution characteristic value) that indicates luminance-distribution characteristics on the addition of luminance Ai is normalized by a shutter speed "a". Used here as the parameter is luminance-addition variance VAR that indicates a variance in the addition of luminance Ai. Luminance-addition variance VAR' normalized by the shutter speed "a", called a normalized luminance-addition variance VAR', is calculated by the following equations:

$$VAR' = VAR/a$$

$$VAR^2 = \{ (A1 - A_{ave})^2 + (A2-A_{ave})^2 + \cdots (An - A_{ave})^2 \}/n = \Sigma\ (Ai^2)/n - (\Sigma\ Ai/n)^2 \quad (1)$$

[0070] The normalized luminance-addition variance VAR' as the luminance-distribution-characteristics parameter requires a decision in that the VAR' is larger than an appropriate reference value as of fail-safe measure-interruption requirement.

[0071] Instead of the VAR', the maximum addition of luminance Amax that indicates the maximum (peak) of the addition of luminance Ai can be used as the luminance-distribution-characteristics parameter.

[0072] The Amax requires a decision in that the maximum addition of luminance Amax' normalized by the shutter speed "a", called normalized maximum addition of luminance Amax', is larger than an appropriate reference value as a fail-safe measure-interruption requirement.

[0073] Another decision in that both the normalized VAR' and the normalized Amax' are larger than the corresponding appropriate reference values can be used as a fail-safe measure-interruption requirement.

[0074] The reason for using the normalized VAR' and Amax' for determination of whether the vehicle is facing the weak sunlight is discussed with reference to FIGS. 10 and 11.

[0075] Fig. 10 shows the un-normalized characteristics of the luminance-distribution-characteristics parameters (VAR and Amax) that were measured in an actual driving test. Images were taken into the weak sunlight from about 300 sec. to about 340 sec. after the start of measurement.

[0076] The measurement of Amax teaches that Amax was measured in a fixed range through the test and hence it is difficult to find out an extreme tendency on a weak-sunlight-facing driving.

[0077] The measurement of VAR shows a peak on about 270 sec. after the start of measurement, which appeared while the vehicle was not facing the sun, and hence it is also difficult to find out an extreme tendency on the weak-sunlight-facing driving.

[0078] FIG. 11 shows the normalized characteristics of the luminance-distribution characteristics parameters (VAR' and Amax').

[0079] Compared to the test results shown in FIG. 10, the results in FIG. 11 show an extreme tendency in which both VAR' and Amax' are extremely increased while the vehicle is facing the weak sunlight.

[0080] It is therefore apparent that these parameters VAR' and Amax' can be used effectively for determining whether the vehicle is facing the weak sunlight.

[0081] Accordingly, the present invention employs the parameters Amax' and VAR' that are obtained by normalizing the parameters Amax and VAR with a shutter speed "a" for determination of the weak sunlight-facing driving in view of the fact that Amax and VAR are the functions of the shutter speed "a".

[0082] The decision in that both Amax' and VAR' are larger than the corresponding reference values as a fail-safe measure-interruption requirement further enhances accuracy of determination on fail-safe measurements.

[0083] The shutter speed, however, tends to be higher on a fair day, and hence the routine proceeds to step S6 (FIG. 5) when the requirements in steps S1, S2, S3, S4 and S5 are all met.

[0084] Sixth requirement: Division of the luminance moment by the total addition of the luminance is equal to or lower than a reference value (step S6).

[0085] Step S6 evaluates the distribution of addition of luminance Ai for each monitoring area Ni from the point of view which is different from step S5.

[0086] FIGS. 12A and 12B show the distribution characteristics of the addition of luminance Ai in regular conditions.

[0087] In detail, FIG. 12A shows an example of the distribution characteristics for a driving condition such that a vehicle is entering a freeway, so that the sky is displayed all over the upper section of the monitor screen.

[0088] FIG. 12B shows another example of the distribution characteristics for a driving condition such that the vehicle is travelling on a road uncovered with snow, which is displayed in the mid section of the monitoring screen, while the ground besides the road has been covered with snow.

[0089] On the other hand, FIGS. 13A and 13B show the distribution characteristics of the addition of luminance Ai while the cameras 1 and 2 are facing a weak sunlight during the sunlight-facing driving.

[0090] The weak-sunlight-facing driving results in a tendency in that high luminance portions being converged on one section corresponding to the sunlight-diffusion disc (FIG. 2) of a monitored image in the horizontal direction. This is shown in FIG. 13A in which the high luminance portions are converged on the mid section of the monitor screen. FIG. 13B shows high luminance portions converged on the right section of the monitor screen.

[0091] Step S6 determines whether the present driving condition is a regular one such as shown in FIG. 12A or 12B or the weak-sunlight-facing driving such as shown in FIG. 13A or 13B.

[0092] For this determination, a luminance center LC and a luminance moment LM are introduced as defined in the following equations:

$$LC = \Sigma(i \times Ai)/\Sigma Ai$$

$$LM = \Sigma (| i - LC | \times Ai) \quad (2)$$

where "i" indicates a monitoring area Ni- number (0 to 31) and Ai indicates an addition of the luminance Ai in the i-th monitoring area Ni, like in step S5.

[0093] The luminance center LC is defined as a horizontal position at which the addition of luminance Ai in the

horizontal direction are converged. The LC is obtained by dividing the total of the product of Ai x " i" (=horizontal position) by the total of Ai.

[0094] For example, when all of the addition of luminance Ai are the same value as shown in FIGF. 14A, the luminance center LC is 15. 5 that lies between 0 and 31. Moreover, when the addition of luminance A0 to A15 are all zero and A16 to A31 are the same value ($\neq 0$), the luminance center LC is 23. 5.

[0095] The luminance moment LM is defined as the total of the product of a distance from the luminance center LC to a horizontal position "i" times the addition of luminance Ai. The moment LM indicates the distribution of the addition of luminance Ai in the horizontal direction on the basis of the luminance center LC. The luminance moment LM becomes small when the addition of luminance Ai is small in overall or the luminance is converged in the vicinity of the luminance center LC.

[0096] Calculated next is the value obtained by dividing the luminance moment LC by the total of addition of luminance ΣAi, or luminance moment LM that is normalized by ΣAi as indicated by the following equation:

$$LM' = LM/\Sigma Ai$$
$$= \Sigma(|i - LC| \times Ai)\ \Sigma Ai \quad \ldots (3)$$

[0097] In normal driving at the distribution characteristics such as shown in FIG. 14A, the luminance moment LM tends to become large because luminance are distributed all over in the horizontal direction.

[0098] On the other hand, in the sunlight-facing driving at the distribution characteristics such as shown in FIG. 14C, the luminance moment LM tends to become small because the luminances are converged in the vicinity of the luminance center LC.

[0099] However, it is sometimes difficult to discriminate the sunlight-facing driving condition from a normal driving condition because the luminance moment LM becomes large for a bright image even in sunlight-facing driving.

[0100] In view of this, the normalized luminance moment LM' that is obtained by dividing the luminance moment LM by the total of addition of luminance Ai and that depends only on luminance distribution is used for the determination in step S6.

[0101] The normalized luminance moment LM' has a tendency of becoming large for the distribution characteristics shown in FIGS. 12A and 12B whereas small in FIGS. 13A and 13B.

[0102] In view of this, step S6 compares the normalized luminance moment the LM' with an appropriate reference value for detecting the weak-sunlight-facing driving condition that is shown in FIGS. 13A and 13B.

[0103] The equation (3) can be modified for a large weight of the addition of luminance Ai for evaluation of Ai distribution as follows:

$$LM' = \Sigma\ (|i - LC| \times Ai^2)/\ \Sigma Ai$$

$$LC = \Sigma(i \times - Ai^2)/\ \Sigma Ai \qquad (4)$$

[0104] In FIG. 5, when all the requirements in steps S1 to S6 are met, or all the fail-safe measure-interruption requirements are met, it is determined that the vehicle is facing a weak sunlight. A count flag Fcnt is then set at "1" (step S12). The count flag Fcnt is set at "0" when a counter K reaches the lower limit value 0 whereas "1" while the counter K is counting up or down ($K \neq 0$).

[0105] The counter K is set at a count value a (> 0) in the following step S13.

[0106] The counter K is used for a fail determining routine such as shown in FIG. 15 for determining whether to take fail-safe measures.

[0107] When the counter K reaches the upper limit value Klim (step S30) due to increment in the weak-sunlight-facing driving condition determining routine, a fail flag NG is set at "1" (step S31). On the other hand, when the counter K reaches the lower limit value 0 (step S32), the count flag Fcnt and the fail flag NG are both reset at "0" (steps S33 and S34).

[0108] Moreover, when the counter K is in the range from the lower limit value 0 to the upper limit value Klim, the routine ends via steps S30 and S32 with no change in the count flag Fcnt and the fail flag NG.

[0109] While a front-view monitoring is interrupted by the fail-safe measures (NG = 1), it will not be resumed (fail-safe measures will not be released) unless the counter K reaches the lower limit value 0.

[0110] On the other hand, while the front-view monitoring is performed (NG = 0), it will not be interrupted by the fail-safe measures unless the counter K reaches the upper lower limit value Klim.

[0111] The counter K starts the count-up when a fail-safe measure-interruption requirement is met. The fail flag NG is set at "1" when such a driving condition continues for a predetermined period (decided based on the upper limit value Klim and the count-up amount α) for taking the fail-safe measures. Monitoring is thus interrupted for avoiding a decrease in monitoring control accuracy in the weak-sunlight-facing driving.

[0112] The count-up amount α is decided according to a count-up amount setting routine shown in FIG. 6. The amount α is decided in accordance with a distance variable and a difference in luminance in left and right cameras (step S20).

[0113] Usually, cameras are facing the sunlight in the sunlight-facing driving and hence the variation in calculation of the distance tends to be larger compared to a normal driving condition.

[0114] In view of such a tendency, the present invention obtains the distance variable in a predetermined area in a monitored image, for example, an area extending in the vertical direction in the image. The count-up amount α is set at a large one when the variable is large. It is also set at a large amount in the sunlight-facing driving due to a larger luminance difference between the left and right cameras compared to the normal driving.

[0115] On the other hand, it is determined that the vehicle (the cameras 1 and 2) is not facing the sunlight if any one (or more) of the fail-safe measure-interruption requirements is (or are) not met through steps S1 to S6 in FIG. 5.

[0116] The routine then proceeds to step S3 in FIG. 6 to determine whether the count flag Fcnt has been set at "1", or the counter K has been counting up or down in step S7. If it is determined as K = 0, the routines will not proceed anymore and ends.

[0117] As disclosed, monitoring is continued without taking any fail-safe measurements during the normal driving condition without facing sunlight and the count K having reached the lower limit value 0, or the fail flag NG having been set at "0".

[0118] On the contrary, when any one (or more) of the fail-safe measure-interruption requirements is (or are) not met through steps S1 to S6, but it is " YES" (Fcnt=1, $K \neq 0$) in step S7, the routine proceeds to step S8.

[0119] Steps S8 to S10 define fail-safe measure-release requirements for the counter K to count up or down to resume functions that have been interrupted by the fail-safe measures. The counter K will count down when a fail-safe measure-release requirement is met whereas count up when a requirement is not met.

[0120] The fail-safe measure-release requirements are not as severe as the fail-safe measure-interruption requirements for avoiding repetition of the fail-safe measures while it is repeated that the vehicle travelling ahead is lost and appeared on the monitoring screen.

[0121] As one of the fail-safe measure-release requirements, it is determined in step S8 whether the shutter speed "a" is 3000 μsec. or lower. If not, or this fail-safe measure-release requirement is met, the routine proceeds to step S11 in which the counter K counts down by a count-down amount β.

[0122] On the other hand, if "YES" in step S8, the routine proceeds to step S9 to determine whether the luminance-addition variance VAR is equal to or larger than the reference value.

[0123] The VTR tends to be large in the sunlight-facing driving condition because, particularly, when facing a strong sunlight, luminance-saturated sections appear on the monitor screen due to smears or sunlight-diffusion discs (FIG. 2) and also blackout sections.

[0124] However, VTR tends to be large not only in the sunlight-facing driving, but also, for instance, in a sunny day, due to a strong contrast between sunny and shade places. It tends to be large, particularly, there is the shade of guard rails or roadside trees along the road.

[0125] In view of such a tendency, the present invention deploys the luminance-addition variance VTR that will not vary so much in the weak-sunlight-facing driving compared to the normalized luminance-addition variance VTR', for the fail-safe measure-release requirements less severe than the fail-safe measure-interruption requirements, to avoid the repetition of fail-safe measures discussed above.

[0126] If" YES" in step S9 (FIG. 6), the routine proceeds to step S13 (FIG. 5) in which the counter K starts count-up. On the other hand, if "NO" in step S9, the routine proceeds to step S10 to determine whether lane markings have been accurately recognized. Accuracy on a lane marking recognition can be used as a fail-safe measure-release requirement for avoiding the repetition of the fail-safe measures discussed above. This is because the road surface will be mostly correctly displayed on the monitor screen and hence the lane marking recognition accuracy will not be lowered so much even in the weak-sunlight-facing driving.

[0127] If the lane marking recognition accuracy has been lowered in step S10, the routine proceeds to step S13 (FIG. 5) in which the counter K starts count-up.

[0128] on the other hand, if the lane marking recognition accuracy is not lowered in step S10, the routine proceeds to step S11 in which the counter K starts count-down.

[0129] The lane marking recognition accuracy can be determined as disclosed in Japanese Patent Application No. 11-269578. The accuracy of lane markings detected on a monitored image is determined based on the number of edges of luminance on the lane markings, the positional relationship (continuity) to the lane markings detected previously and parallelism between left and right lane markings. High lane marking recognition accuracy is achieved as the

number of edges of luminance is larger, the lane markings detected in the present image more continues to the previously detected markings and the detected left and right markings are more parallel to each other.

[0130] As clearly understood from the foregoing disclosure, the fail-safe measure-release requirements (count-down requirements for the counter K) are as follows:

(1) the shutter speed "a" is higher than 3000 μse., or
(2) if not, the luminance-addition variance VAR is smaller than the reference value and lane marking recognition is accurate.

[0131] As disclosed, the present invention monitors parameters such as the luminance-distribution characteristics parameter, the number of edges of luminance, the upper and lower luminance saturation factors and the luminance moment for detection of a weak-sunlight-facing driving condition.

[0132] The fail-safe measures can therefore be taken exactly during the weak-sunlight-facing driving, thus offering a highly reliable vehicle front-view monitoring system.

[0133] Particularly, in the present invention, several monitoring areas are set on the monitor screen, which are slit-like areas extending vertically on a monitored image for obtaining the luminance-distribution characteristic values (the luminance-addition variance VAR and the maximum addition of luminance Amax) in the horizontal direction of the image.

[0134] The luminance-distribution characteristic values are normalized using a shutter speed "a" for obtaining parameters (the luminance-addition variance VAR' and the normalized maximum addition of luminance Amax') that are highly related to weak-sunlight-facing driving.

[0135] The normalized parameters VAR and Amax' can be used for detection of a weak-sunlight-facing condition, which is more accurate than using the un-normalized parameters VAR and Amax as the fail-safe measure-interruption requirements.

[0136] The fail-safe measure-release requirements are set as including several conditions in addition to a weak-sunlight-facing driving condition so that it is not so severe than those of the fail-safe measure-interruption requirements.

[0137] This requirement setting avoids the repetition of unnecessary fail-safe measures such as the warning which could irritate the driver while it is repeated that the vehicle travelling ahead is lost and appeared on the monitoring screen.

[0138] The fail-safe measure-interruption requirements include the normalized Luminance-addition characteristic values VAR' and Amax' whereas the fail-safe measure-release requirements include VAR and Amax, the parameters different from VAR' and Amax because those are not normalized.

[0139] Moreover, the fail-safe measure-release requirements include the accuracy on the lane marking recognition that is not deployed for the fail-safe measure-interruption requirements.

[0140] Deploying different parameters for the fail-safe measure-interruption/release requirements offers flexible fail-safe requirement settings that match an actual driving condition compared to setting in which reference values are changed between the interruption/release requirements for the same parameters.

[0141] The count-up amount a is adjusted based on the luminance difference between the left and right cameras and distance data variable.

[0142] This adjustment offers variable settings for a fail-safe determination time from a moment at which the fail-safe measure-interruption requirements are met to a moment of taking fail-safe measures in accordance with actual driving conditions.

[0143] Disclosed so far is the vehicle front-view monitoring system that takes fail-safe measures against a weak-sunlight-driving condition in which the vehicle is travelling as facing the weak sunlight so that sunlight-diffusion discs appear on the monitor screen.

[0144] However, the present invention is applicable to not only such a weak-sunlight-driving condition but also other optical phenomena such as smear occurring on a monitoring screen.

[0145] As disclosed, according to the present invention, optical irregularities occurring on the monitored images due to optical interfering can be accurately detected, thus, the fail-safe measures can be taken swiftly in response to such optical phenomena for securing the safety driving.

[0146] It is further understood by those skilled in the art that the foregoing description is a preferred embodiment of the disclosed device and that various change and modification may be made in the invention without departing from the scope thereof.

Claims

1. A vehicle front-view monitoring system for taking fail-safe measures comprising:

a camera device for taking an image of a view in front;
a calculator for calculating luminance data on the image; and
a determination section for determining whether there is a fail occurring on the monitoring system based on the luminance data, the fail-safe measures being taken if the fail is occurring.

2. The vehicle front-view monitoring system according to claim 1, wherein the luminance data indicate luminance-distribution characteristic values indicating a horizontal luminance-distribution on the image.

3. The vehicle front-view monitoring system according to claim 2, wherein the determination section determines the fail based on a parameter obtained by the calculator and normalizes the luminance-distribution characteristic values by a shutter speed for the camera device.

4. The vehicle front-view monitoring system according to claim 2 or claim 3, wherein the luminance-distribution characteristic values include the maximum value of addition of luminance on the image.

5. The vehicle front-view monitoring system according to any of claims 2 to 4, wherein the luminance-distribution characteristic value include a luminance-addition variance on the image.

6. The vehicle front-view monitoring system according to any of claims 1 to 5, wherein the luminance data include the number of data related to luminance edges in a predetermined monitoring area on the image.

7. The vehicle front-view monitoring system according to claim 6, wherein the number of data is the number of luminance edges.

8. The vehicle front-view monitorina system according to claim 6 or claim 7, wherein the number of data is the number of distance data obtain by a pair of cameras of the camera device.

9. The vehicle front-view monitoring system according to any of claims 6 to 8, wherein the monitoring area is set on the upper section of the image where a vehicle running ahead is displayed.

10. The vehicle front-view monitoring system according to any of claims 1 to 9, wherein the calculator calculates a luminance center as the luminance data, the luminance center corresponding to a horizontal position on the image at which luminance are converged, and the determination section determines the fail by evaluating the horizontal luminance distribution on the image based on the luminance center.

11. The vehicle front-view monitoring system according to claim 10, wherein the calculator calculates luminance moment indicating the horizontal luminance distribution based on the luminance center and the determination section determines the fail based on the luminance moment.

12. The vehicle front-view monitoring system according to claim 10 or claim 11, wherein the calculator further calculates the number of data as another parameter related to luminance edges in a predetermined monitoring area on the image, the determination section determining the fail based on the parameters.

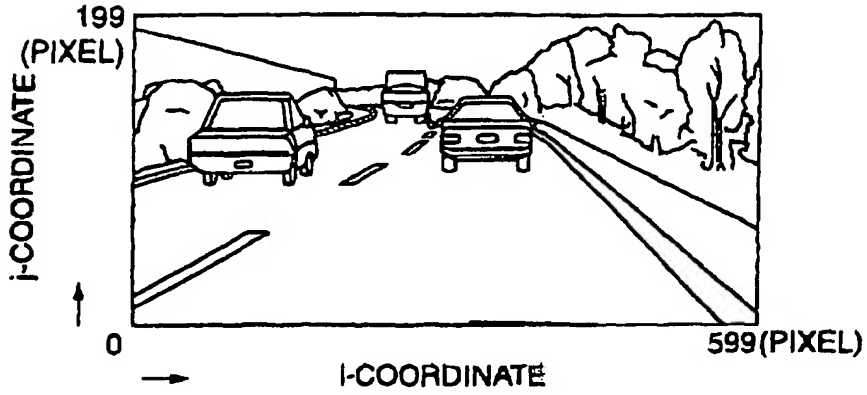

FIG.1

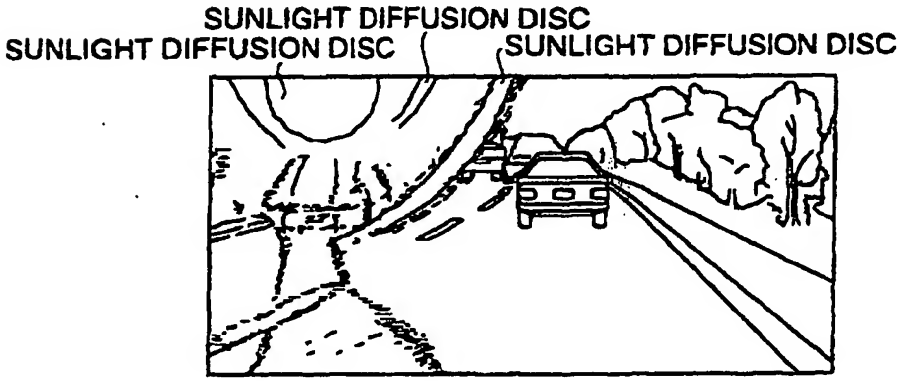

FIG.2

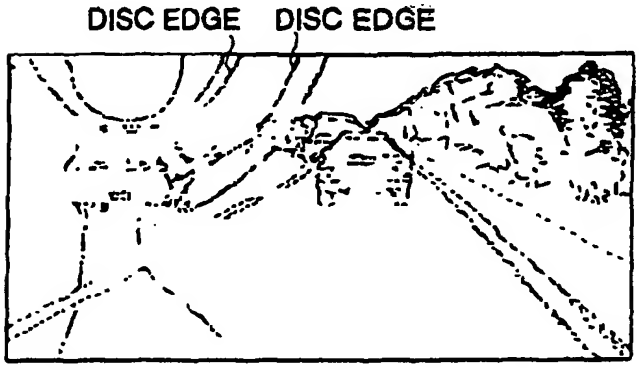

FIG.3

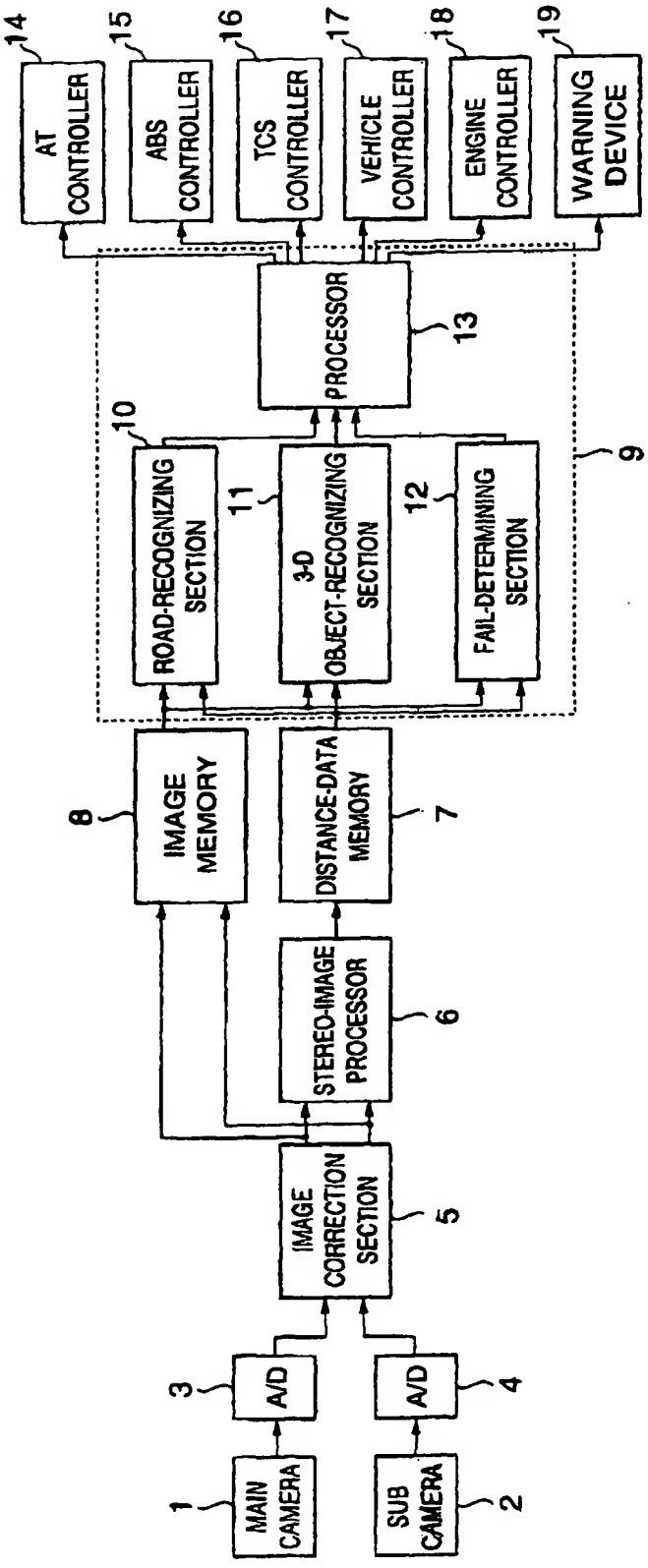
MAIN CAMERA
SUB CAMERA
A/D
A/D
IMAGE CORRECTION SECTION
STEREO-IMAGE PROCESSOR
IMAGE MEMORY
DISTANCE-DATA MEMORY
ROAD-RECOGNIZING SECTION
3-D OBJECT-RECOGNIZING SECTION
FAIL-DETERMINING SECTION
PROCESSOR
AT CONTROLLER
ABS CONTROLLER
TCS CONTROLLER
VEHICLE CONTROLLER
ENGINE CONTROLLER
WARNING DEVICE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

FIG.4

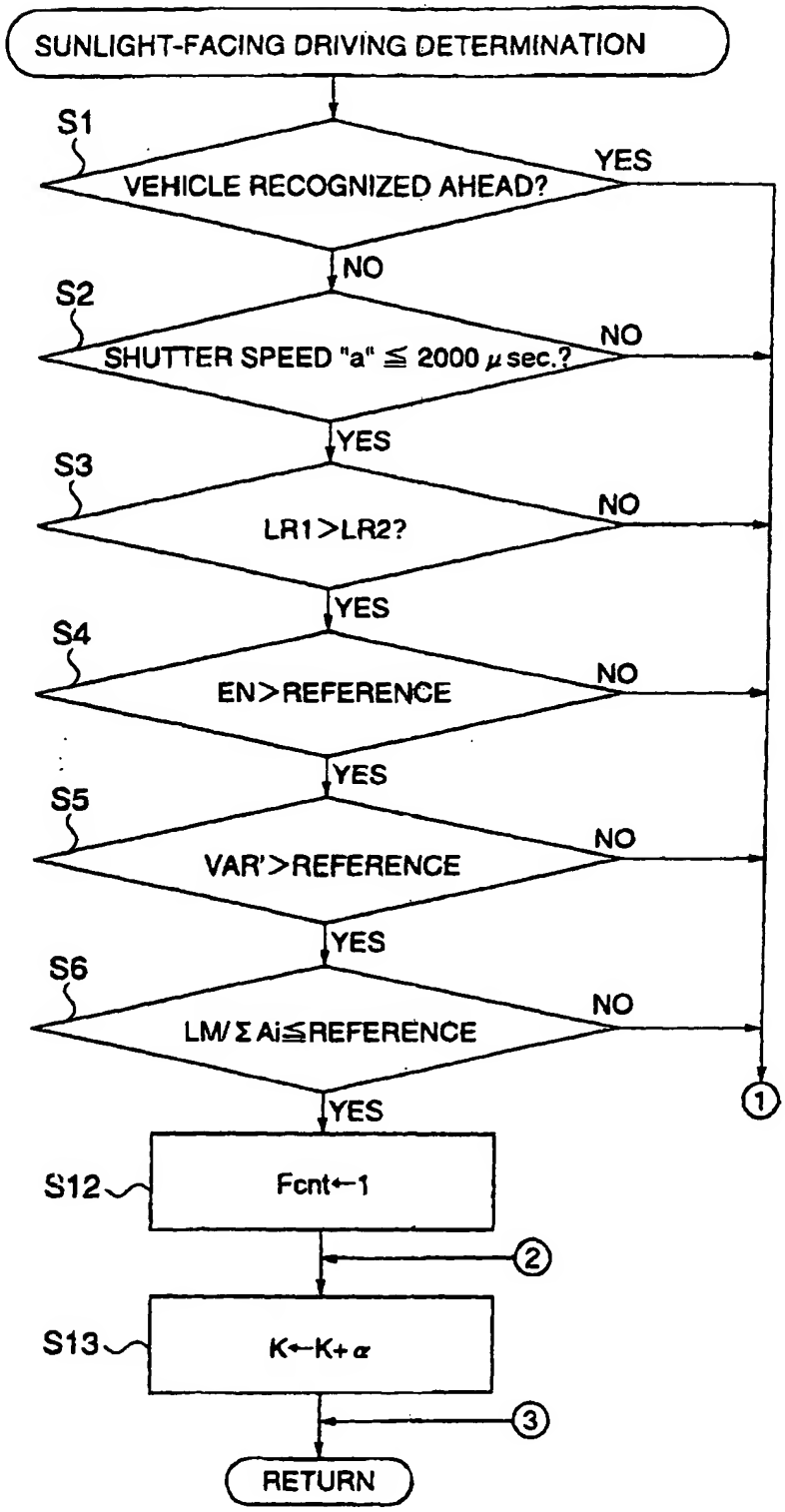
SUNLIGHT-FACING DRIVING DETERMINATION
S1
VEHICLE RECOGNIZED AHEAD?
YES
NO
S2
SHUTTER SPEED "a" ≦ 2000 μ sec.?
NO
YES
S3
LR1>LR2?
NO
YES
S4
EN>REFERENCE
NO
YES
S5
VAR'>REFERENCE
NO
YES
S6
LM/ΣAi≦REFERENCE
NO
YES
①
S12
Fcnt←1
②
S13
K←K+α
③
RETURN

FIG.5

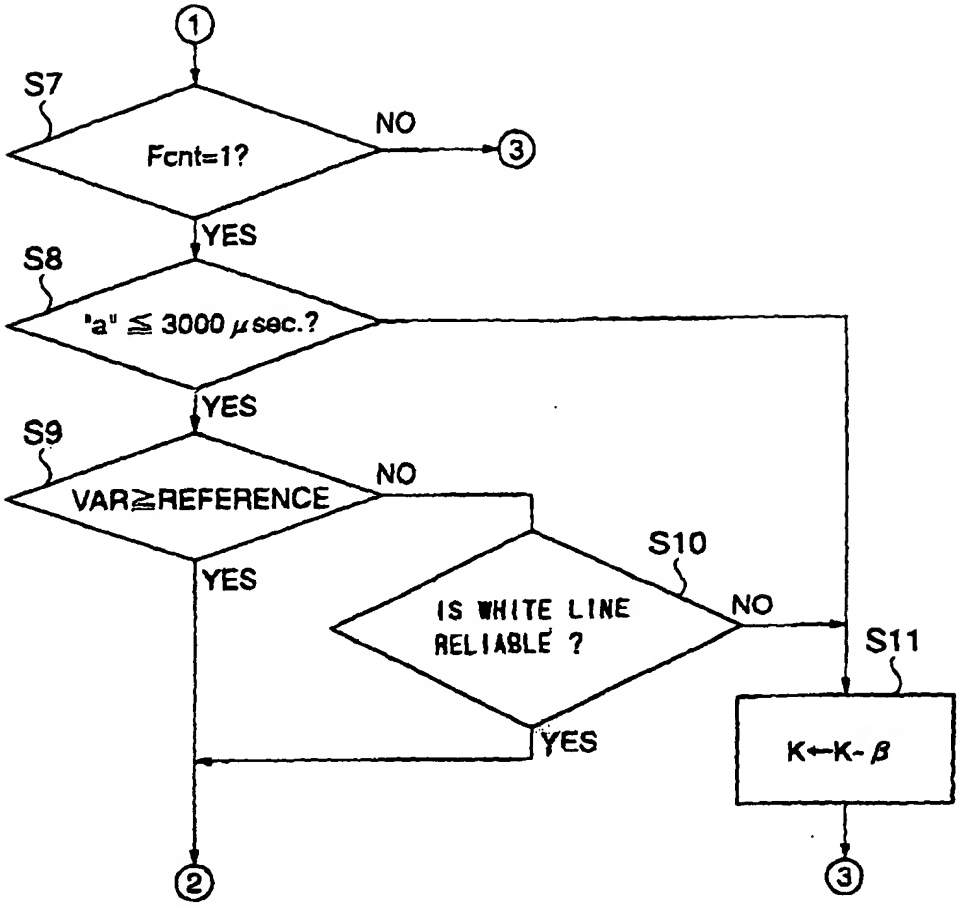
1
S7
Fcnt=1?
NO
3
YES
S8
"a" ≦ 3000 μsec.?
YES
S9
VAR≧REFERENCE
NO
YES
S10
IS WHITE LINE RELIABLE ?
NO
YES
S11
K←K-β
2
3

FIG.6

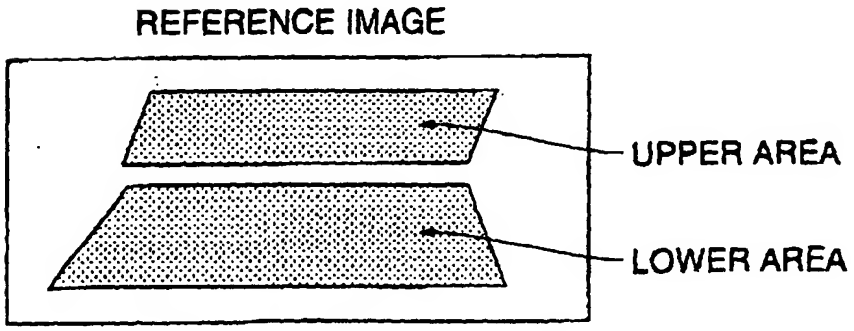
REFERENCE IMAGE
UPPER AREA
LOWER AREA

FIG.7

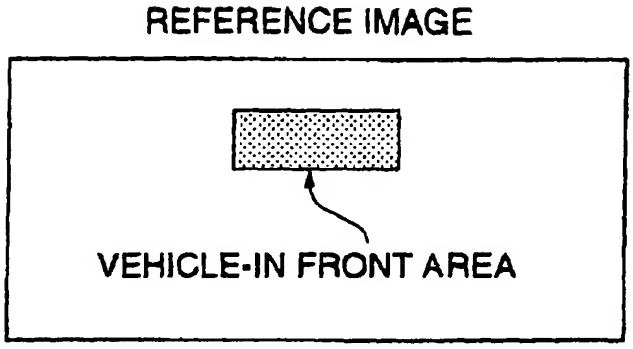
REFERENCE IMAGE
VEHICLE-IN FRONT AREA

FIG.8

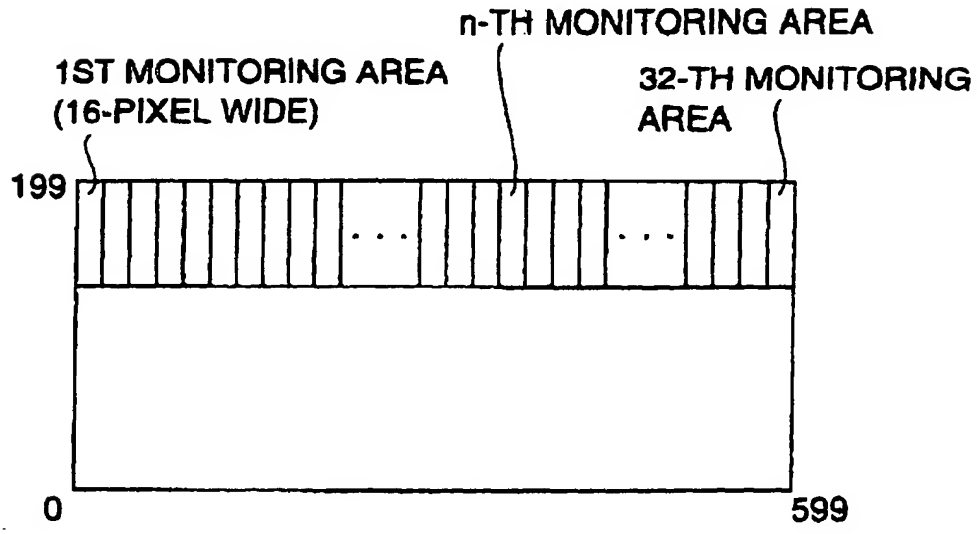
n-TH MONITORING AREA
1ST MONITORING AREA
(16-PIXEL WIDE)
32-TH MONITORING
AREA
199
0
599

FIG.9

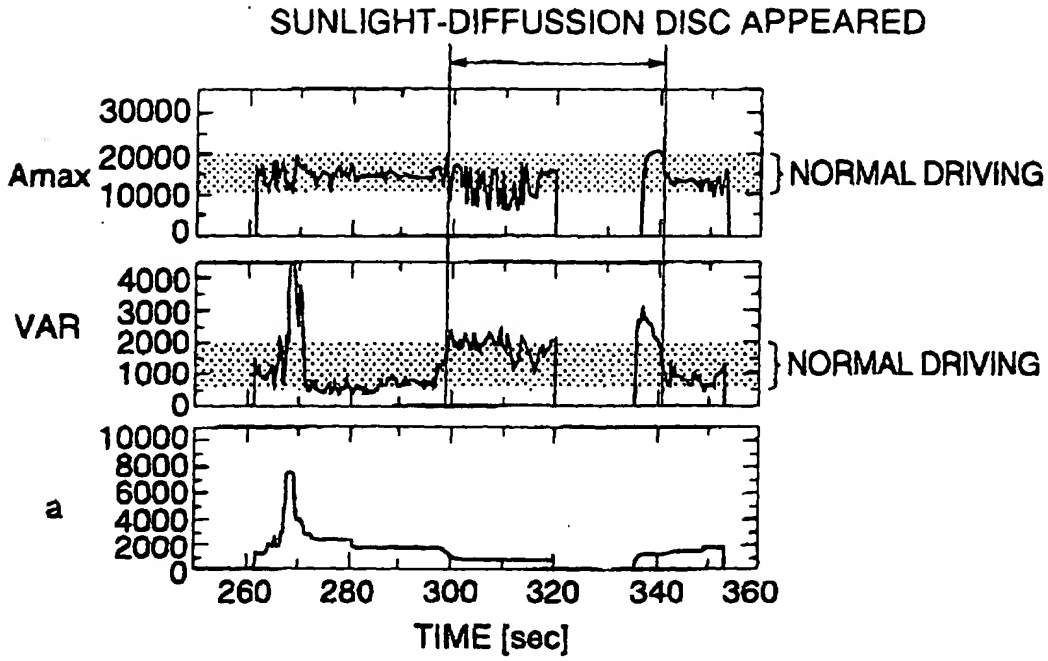
SUNLIGHT-DIFFUSSION DISC APPEARED
Amax
30000
20000
10000
0
NORMAL DRIVING
VAR
4000
3000
2000
1000
0
NORMAL DRIVING
a
10000
8000
6000
4000
2000
0
260
280
300
320
340
360
TIME [sec]

FIG.10

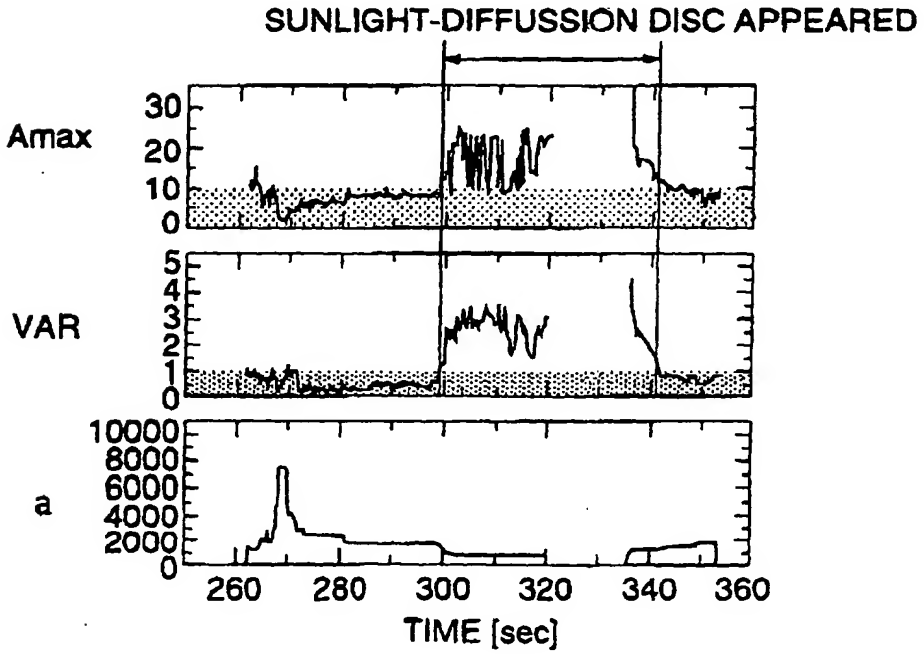
SUNLIGHT-DIFFUSSION DISC APPEARED
Amax
30
20
10
0
VAR
5
4
3
2
1
0
a
10000
8000
6000
4000
2000
0
260
280
300
320
340
360
TIME [sec]

FIG.11

FIG.12A

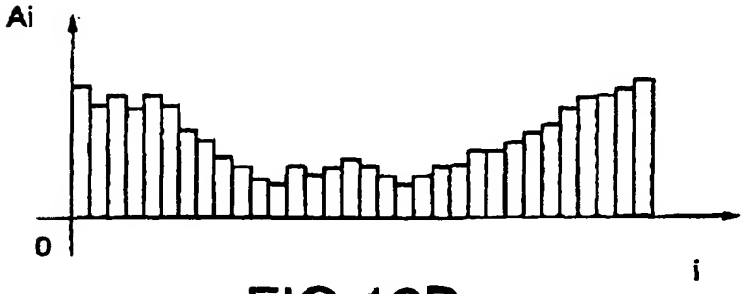

FIG.12B

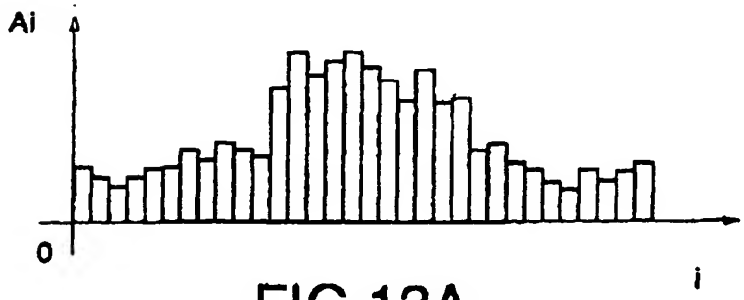

FIG.13A

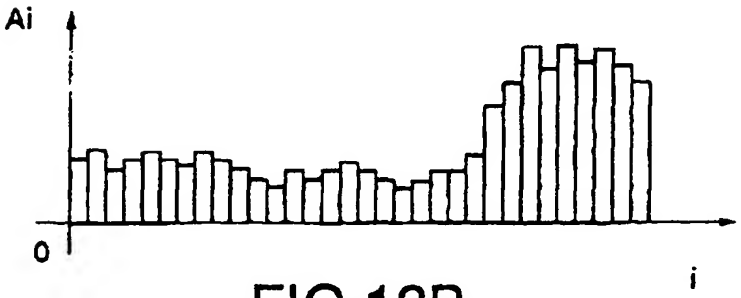

FIG.13B

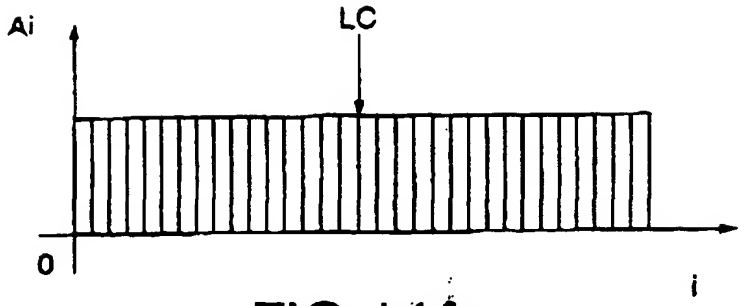

FIG.14A

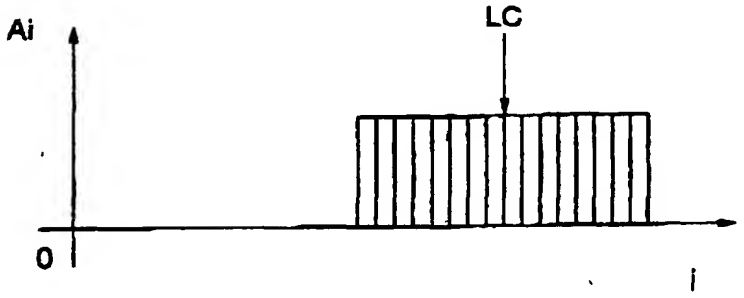

FIG.14B

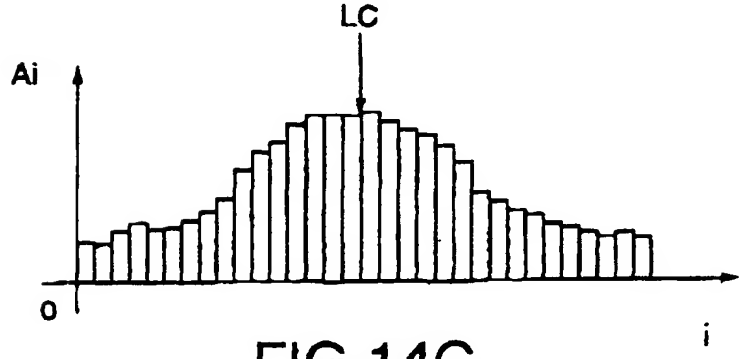

FIG.14C

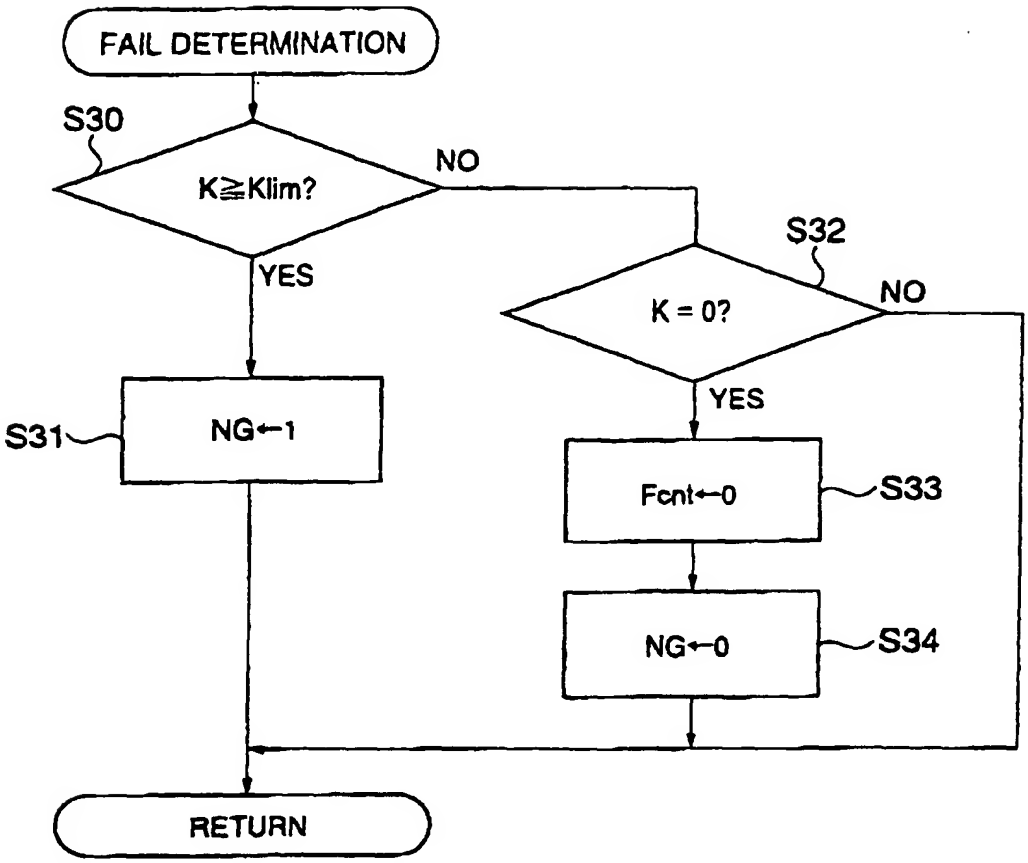
FAIL DETERMINATION
S30
K≧Klim?
NO
YES
S32
K = 0?
NO
YES
S31
NG←1
Fcnt←0
S33
NG←0
S34
RETURN

FIG.15

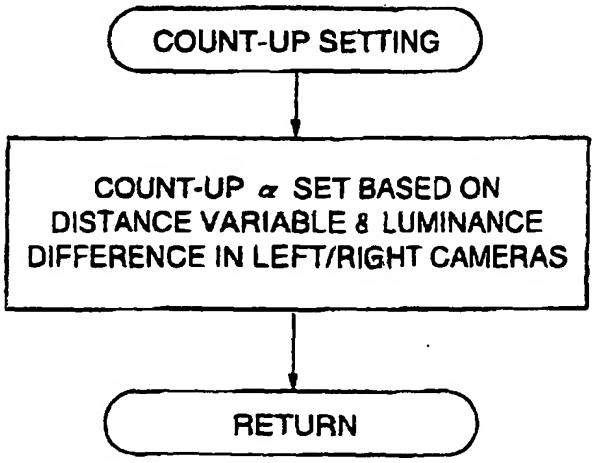
COUNT-UP SETTING
COUNT-UP α SET BASED ON DISTANCE VARIABLE & LUMINANCE DIFFERENCE IN LEFT/RIGHT CAMERAS
RETURN

FIG.16